§12. The Role of H⁻ Energy and Electric Field in the Extraction Region for H⁻ Extraction Probability of a Negative Ion Source

Matsumoto, Y., Nishiura, M.
Wada, M. (Doshisha Univ.)
Sasao, M. (Tohoku Univ.)
Yamaoka, H. (RIKEN)

Hydrogen negative ion sources are important devices for NBI(neutral beam injectors) systems. To develop higher efficient ion sources, many H^- studies have been reported. However, H^- transport, which is also essential knowledge to improve efficiency of ion sources, was not experimentally measured, because we had no experimental method for this purpose. Therefore, we developed the new measurement method of H^- transport, PD-FC (Photodetachment with Faraday Cup). This method gives us the spatial distribution of the number of H^- ions that are extracted from an ion source. We can estimate the H^- extraction probability from the combination of PD-FC results and H^- density profiles, which can be measured by PD-LP(Photodetachment with Langmuir probe)[1]. The experimental apparatus is showed in Fig.1. These experimental data are analyzed to study the physical mechanism of H^- extraction by the numerical approach which calculates H^- orbits in an ion source plasma with Monte Carlo method.

Fig.2(a) shows the experimental results of the spatial distributions of the H^- extraction probability under several gas pressure conditions. From this figure, the extraction probability is affected by gas pressure conditions and the maximum value is observed around 1Pa. It is considered that this gas pressure dependence is caused by the change of H^- energy and the electric field in the extraction region; The electric field exists near the plasma electrode (PE) and prevents H^- ions from reaching the extraction hole. Besides, H^- transport is strongly affected by the electric field near the extraction hole, because H^- energy in ion sources are almost room temperature and much lower than plasma potential in this region. To confirm the change of H^- energy and the electric field by gas pressure change, they are measured by movable Langmuir probe in these gas pressure conditions. As the result of the measurement, lower H^- energy and lower electric field are observed in higher gas pressure condition. The lower H^- energy makes it difficult that H^- ions arrive to the extraction hole, while, the decrease of the electric field makes it easy. From only this experimental data, we cannot determine whether these parameters are key factors of H^- extraction mechanism or not. We should quantitatively analyze in order that the influence of them for the extraction probability is clarified. Therefore, we carry out more detail analysis utilizing the numerical approach with Monte Carlo calculation. Extraction probabilities are calculated with many H^- energy and electric field situations. As the result of the calculation, we find the dependence of the extraction probability, *P(Z)*, on H^- energy, *K(Z)*, and the electric field, *E*, as follow equation.

$$P(Z) \propto \exp\left(-\alpha \cdot eE \cdot Z \big/ K(Z)\right) \qquad (1)$$

Z is the distance from PE, α is the coefficient whose value is about 1.5.

Fig.2(b) shows gas pressure dependence of the spatial distribution of the extraction probability estimated by eq.(1) using the experimental data of the H^- energy and electric field. We can see the same tendency between Fig.2(a) and (b) below 1.2Pa. Though discrepancy between experiment and theory is observed above 2Pa, we conclude that H^- energy and electric field near the PE are key factors for the H^- extraction mechanism, especially in low gas pressure conditions.

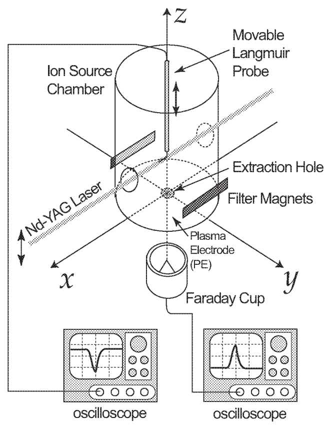

Fig. 1. Experimental apparatus

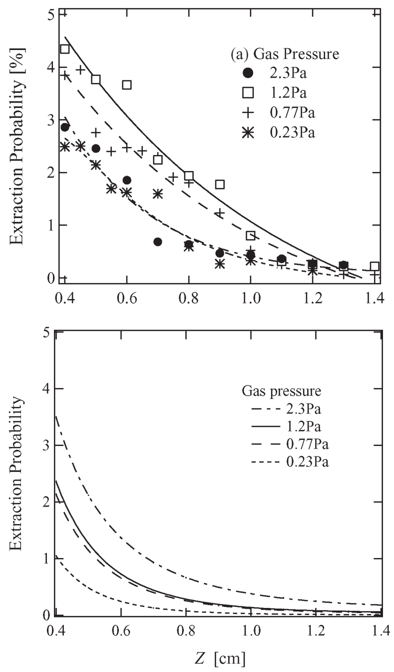

Fig. 2. The spatial distributions of the extraction probability. (a) experiment (b) calculation

Reference

1) Matsumoto, Y., Nishiura, M., Matsuoka, K., Sasao, M.,Wada, M., Yamaoka, H., Thin Solid Films (To be published)